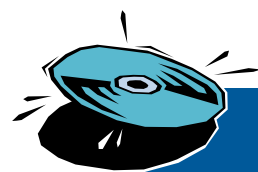


MATERIALS TECHNOLOGIES

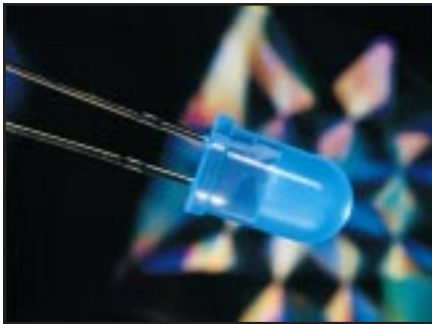
Think of BMDO technology
transfer the next time you

- View an electronic display
at an outdoor stadium.
- Drink a cool, refreshing
glass of water.
- Boot up your computer
and access the disk drive.
- Add a lubricant to your
car's engine oil.



SILICON CARBIDE IS READY FOR PRIME TIME

Process technology for low-cost, low-defect silicon carbide is enabling cutting-edge electronic devices, and paving the way for other novel components.



■ Cree's scientists created a light-emitting diode (pictured above) that emits an intense, brilliant blue light when an electrical current is applied.



■ Lab-created moissanite gemstones (pictured above) are being marketed to the jewelry industry as a substitute for diamonds.

The physical and electronic properties of silicon carbide (SiC) make it an attractive semiconductor material for the 21st century. For example, SiC's wide energy bandgap will enable the creation of new electronic devices that can operate in extremely high temperatures or emit and detect short wavelength light. However, improvements in SiC crystal growth and device fabrication processes are needed before these devices can be scaled up and incorporated into electronic systems.

Cree Research, Inc. (Durham, CA), has put to use new process technology that overcomes many of the basic technical obstacles that have blocked the commercialization of SiC semiconductors. Cree's technology significantly reduces the defect density and cost of the company's SiC wafers, making the material commercially viable for some uses and nearly so for many others. In addition, it is enabling the company to develop a wide range of advanced semiconductor electronic products, such as blue light-emitting diodes (LEDs) and displays.

Many of Cree's process innovations can be traced to the SiC research it performed under several BMDO contracts. BMDO's original vision of space-based systems required radiation-hardened electronics. This hardening property allays the fear of space radiation degrading or disrupting the operation of electronic devices and components on monitoring, tracking, and even weapons-carrying satellites.

Colorful splash. The company's first commercial products using this SiC process technology are its blue LEDs. Cree currently sells LEDs to manufacturers who incorporate them into LED lamps. For example, Cree's largest customer, Siemens A.G., is using the blue LED for automobile dashboard lighting. Other commercial applications for blue LEDs include large-scale flat-panel displays, color recognition sensors, color slide and film scanners, and digital color photographic printers. As production costs decrease and volume increases, Cree expects to see broader applications emerge for its blue LEDs.

Another commercial product that benefits from Cree's SiC process technology is the Real Color Module™, a device only three inches thick and loaded with LEDs capable of representing the entire color spectrum. The module provides a low-cost and effective way of displaying text messages, which can be easily changed and updated. Near-term potential applications for the module include

gaming, casinos, and advertising displays. Recently, Rainbow Vision Company, Ltd., placed Cree's largest one-time order for 800 Real Color Modules. The devices will be used in a live-action replay board for a sports arena.

In addition to these commercial products, Cree has developed a highly successful business using the process technology to manufacture and supply SiC wafers to corporate, government, and university programs. These customers are, in turn, using these products to develop new high-frequency, high-power, and high-temperature devices. Cree recently concluded an agreement to supply Asea Brown Boveri AB, a manufacturer of SiC power semiconductors, with SiC wafers worth a total of \$2.4 million.

On the horizon. Cree is banking on the future potential of its SiC process technology by investigating potential business opportunities in blue lasers, microwave devices, and power devices. For example, Cree's blue LED research and development efforts have paved the way for developing a blue laser. Recently, the company validated the use of SiC as a viable substrate for blue lasers by showing a pulsed and continuous wave laser operation. Blue lasers are expected to enable a dramatic increase in optical data storage capacity. Because of the blue laser's short wavelength, it could increase storage capacity fourfold.

To generate a new level of commercial interest in SiC microwave devices, Cree recently demonstrated a high-powered SiC metal-semiconductor field-effect transistor. Silicon-based microwave products capable of operating at higher power levels are currently available, but these are typically multiple-chip packages. SiC microwave transistors, if packaged in a single-chip product, could offer power levels substantially higher than other solid-state products now on the market.

And on a completely different track, Cree serendipitously created a sparkling new business opportunity for colorless SiC crystals. While improving the SiC growth process, Cree's scientists accidentally synthesized clear moissanite, a carbon-based mineral that has physical characteristics closer to diamond than any other known gemstone material. Recognizing this material could be easily mistaken for diamond, Cree formed a business alliance with C3, Inc., to explore the jewelry market. Using Cree's colorless SiC crystals, C3 is now, or will soon be, marketing moissanite gemstones through jewelry retailers in 47 U.S. cities.

■ For more information, contact Neal Hunter via telephone at (919) 361-5709 or via E-mail at neal_hunter@cree.com. You can also visit Cree's Web site at <http://www.cree.com>.



What Does It Mean to You?

Low-cost, defect-free silicon carbide is enabling many commercial products, from full-color displays and moving message signs to high-power radio frequency and microwave transmitters.



What Does It Mean to Our Nation?

Silicon carbide technology can lead to more efficient power transistors for lighting, heating, and air conditioning products, which could reduce national energy consumption and, in turn, reduce pollution resulting from energy production.

Tech Trivia

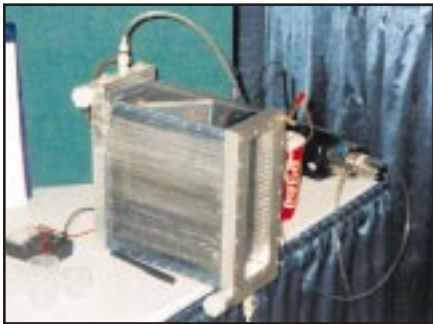
When incandescent lights for the display on the Goodyear blimp *Spirit of Akron* were replaced with brighter light-emitting diodes, what was the result?

- A. A decrease of 250 pounds
- B. A decrease of 500 pounds
- C. An increase of 250 pounds
- D. An increase of 500 pounds

For the answer, see page 74.

CARBON AEROGEL REALLY CLEANS UP WATER

An energy-efficient water treatment tool that makes salty water safe to drink offers new hope to countries blighted by serious water shortages.



■ This water purification unit (pictured above) contains 1,000 square feet of carbon aerogel surface area, yet occupies only a few cubic feet of space.



■ Using carbon aerogel (pictured above) like a microscopic sponge, capacitive deionization is an efficient, economical process for purifying water.

How about a cool, refreshing cup of seawater? In California, the towns of Santa Barbara and Avalon have begun using desalinization methods to remove the salt from seawater, making it suitable for drinking. Desalination is not used much at the moment because it is too expensive. But as both the demand for fresh water and our population increase, you can expect to see more desalination occurring, especially in areas such as California and Texas.

Other countries, too, are experiencing serious water shortages. According to an analysis by Population Action International, more than 430 million people—8 percent of the world's population—are living in countries affected by water stress or outright scarcity. For example, China now officially recognizes that 300 of its largest cities are facing water scarcity.

But the world may soon change the way it looks at salty water, thanks to capacitive deionization (CDI) technology recently developed by Lawrence Livermore National Laboratory (Livermore, CA). An energy-efficient and economical process, CDI uses electrochemical cells treated with a unique material to extract salt and other nonorganic contaminants from water. In certain regions of the United States, and in underdeveloped countries around the globe, CDI units could sustain water and ease scarcity.

Frozen smoke. The key to CDI is carbon aerogel, a highly porous material with nanometer-size cells. In the early 1990s, carbon aerogel research at the lab was partially funded by BMDO's space power program to develop lighter batteries. Made of 96 percent air, carbon aerogel appears more like dark frozen smoke than gel. An intriguing characteristic of this material is its large "internal" surface area. If you could flatten out all of the surfaces lining the tiny pores within a sugar-cube-size piece of carbon aerogel, researchers believe the surface would cover five basketball courts. This versatile manmade material promises a wide range of uses, from insulating windows and appliances to extracting salt from seawater.

The Far West Group, Inc. (FWG; Tucson, AZ), a water resources management business, recognized the worldwide potential of CDI for water treatment services. In 1997, the company established a licensing agreement with the lab to commercialize CDI technology. A second license was established to ensure that FWG could manufacture enough carbon aerogel to support its commercial plan.

CDI is better than many of today's desalination options. "CDI systems would consume considerably less energy per unit of purified water than competing technologies, such as thermal distillation or reverse osmosis (RO)," says Jack Reese, FWG's vice president of marketing. "In fact, CDI could eventually replace RO because of greater energy efficiency and lower maintenance costs. And, when the desalinization technology is needed only on a seasonal or periodic basis, CDI has much lower costs than competing technologies because of its indefinite shelf life." Carbon aerogel will store for years without degradation.

Salt bricks. Among the many business opportunities for CDI systems is treating brackish and salty water, providing drinkable water and agricultural-grade water for towns and farms in water-scarce regions. In addition, FWG believes that it could spin off another business that sells the salt it removes from the treatment process. For example, the company is investigating a recent discovery that salt bricks stronger than concrete can be made. Using CDI, semiconductor manufacturers could produce ultrapure water for semiconductor manufacturing. Another application of CDI is extracting harmful contaminants from waste water, which can help industry reclaim heavy metals or hazardous materials from waste streams.

FWG has implemented a multifaceted approach to commercialization. In addition to demonstrating CDI's capabilities in both the United States and abroad, the company is consulting with Boeing Aerospace and Interglobal, Inc., for international distribution. FWG recently succeeded in obtaining \$375,000 from Electric and Gas Technology to finance the installation of a proof-of-performance system in Carlsbad, California. Additional funding is being sought to speed development of this technology.

FWG is steadily moving toward a final design. The company has reduced the weight of the original CDI prototype unit by 90 percent and significantly cut manufacturing costs. Looking ahead, it hopes to start building CDI systems in 1999.

■ For more information, contact Clark Vaught via telephone at (520) 293-9778 or via E-mail at farwest@farwestgroup.com. You can also visit Far West Group's Web site at <http://www.farwestgroup.com>.



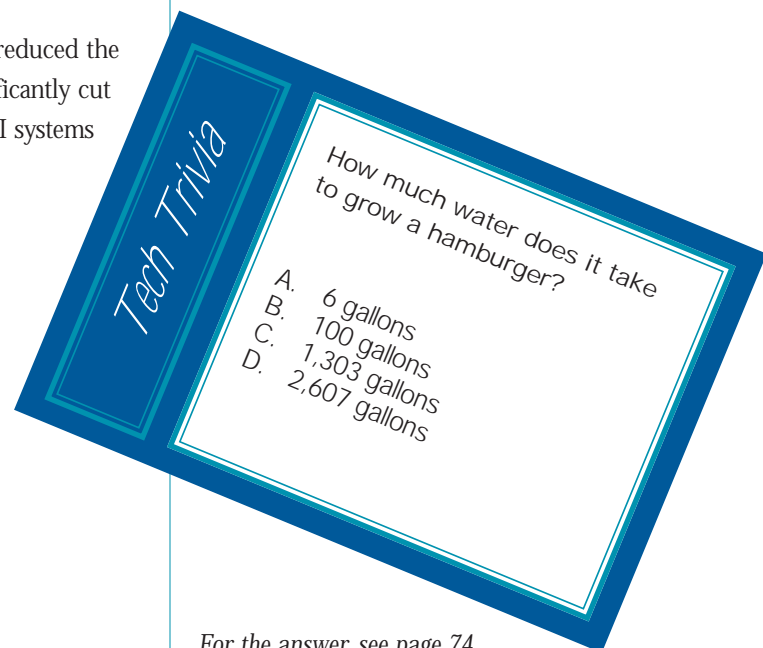
What Does It Mean to You?

With capacitive deionization, you can remove enough salt in brackish and sea water to drink it or use it to sustain farms and lawns.



What Does It Mean to Our Nation?

Capacitive deionization can help water-scarce regions like California and Texas increase freshwater supplies for domestic and agriculture applications, potentially eliminating water-use restrictions.



For the answer, see page 74.

ALLOYS MAKE LOSING WEIGHT EASY

Aluminum-beryllium alloys fill the need for stiff, lightweight materials in golf clubs, communications satellites, and computer disk drives.



■ Precision investment-cast Beralcast® components (pictured above) are used in a wide variety of aerospace, defense, and commercial applications.

Manufacturers have long recognized beryllium for its superior attributes—its light weight, high stiffness, and superior ductility. But the dark grey metal is expensive and brittle, making it difficult to mass-produce into parts, especially complex ones. So far, commercial industries have shied away from using beryllium in their products, resorting to less exotic materials such as aluminum.

Over the years, many attempts have been made to combine beryllium and aluminum, which could theoretically produce parts that perform better than those made of conventional materials, at a price much more affordable than that of pure beryllium. Although simple enough in concept, the alloy's production was hindered for many years because conventional manufacturing techniques were inefficient and wasteful.

Starmet Corporation (Concord, MA), formerly Nuclear Metals, Inc., has developed a method for mass-producing parts made from a family of materials called Beralcast® using aluminum-beryllium alloys. Its casting process allows very complex near-net and net shapes to be fabricated with little or no finished machining—an industry first. In general, any part that can be investment cast in aluminum can also be investment cast in Beralcast. For example, aluminum-based armatures and support structures for high-end computer disk drives and communications satellites, respectively, have been successfully reproduced in Beralcast.

Successful trio. The key to Starmet's success is three new alloys, namely Beralcast 363, 191, and 310. These materials have a fine-grain, homogenous, as-cast microstructure. Their composition is designed to minimize the effects of segregation, porosity, and low strengths. Therefore, they can be readily cast into complex shapes with greatly improved strength and ductility and significantly reduced weight, as compared with other competing materials. Starmet developed the Beralcast process several years ago with validation funding from BMDO contracts for ballistic missile defense systems.

Although difficult to achieve, Starmet's breakthrough provides important technology for weight-critical and stiffness-critical programs. "In making Beralcast alloys, it took us over 400 attempts to find the right combinations of aluminum, beryllium, and trace elements," says Frank Vumbaco, Starmet's vice president of corporate communications. "Beralcast parts are 22 percent lighter than alu-

minum components but have the stiffness of steel. Because of this stiffness, parts can be redesigned using thinner walls. As a result, finished Beralcast parts could weigh half as much as aluminum ones.”

Starmet’s development of Beralcast led to the spinning out or formation of several companies, including two wholly owned subsidiaries, Starmet Commercial Casting and Starmet Aerocast. Another company, TrioStar, also formed to take advantage of Beralcast. In 1997, several commercial and military groups established agreements with these companies to use Beralcast in their systems.

For example, Starmet Commercial Casting has received more than \$1 million in contracts from four major companies to use Beralcast material in high-end computer disk drives. Armatures made of Beralcast alloys allow disk drives to retrieve more electronic data at a faster rate than those made from aluminum because the material’s stiffness and resulting damping qualities are 4 to 10 times better than aluminum, depending on the driving and resonance frequencies. Starmet Commercial Casting has been manufacturing prototype Beralcast components and expects to mass-produce computer disk drive armatures in mid-1999.

Flying high. Teaming with Advanced Product Laboratories and R-Cubed Composites, Starmet Commercial Casting also formed a joint venture corporation in late 1997, called TrioStar (West Jordan, UT). TrioStar offers the unique capability to integrate resin matrix composite and metallic structures into a unified design for application in such weight-critical programs as low-Earth-orbiting satellites for global communications networks. The bulk of the technology also surrounds Starmet’s patented family of Beralcast alloys. Because Beralcast is light in weight, has a high modulus of elasticity, and can be precision cast for three-dimensional material stability, these alloys are attractive for advanced sensor and guidance structures in flight and satellite systems.

On a lighter note, Starmet is investigating the use of Beralcast in golf clubs and high-end racing bicycles. Working with several equipment manufacturers, the company is testing Beralcast alloys for replacing the club’s head and shaft, which may increase the speed of the user’s swing. It also has supplied Beralcast alloys to Beyond Fabrications, producers of beryllium-based bicycles. The Beralcast frames of these bikes weigh about two pounds, which is about half the weight of aluminum frames.

■ For more information, contact Frank Vumbaco via telephone at (978) 369-5410, ext. 296, or via E-mail at fvumbaco@starmet.com. You can also visit Starmet’s Web site at <http://www.starmet.com>.



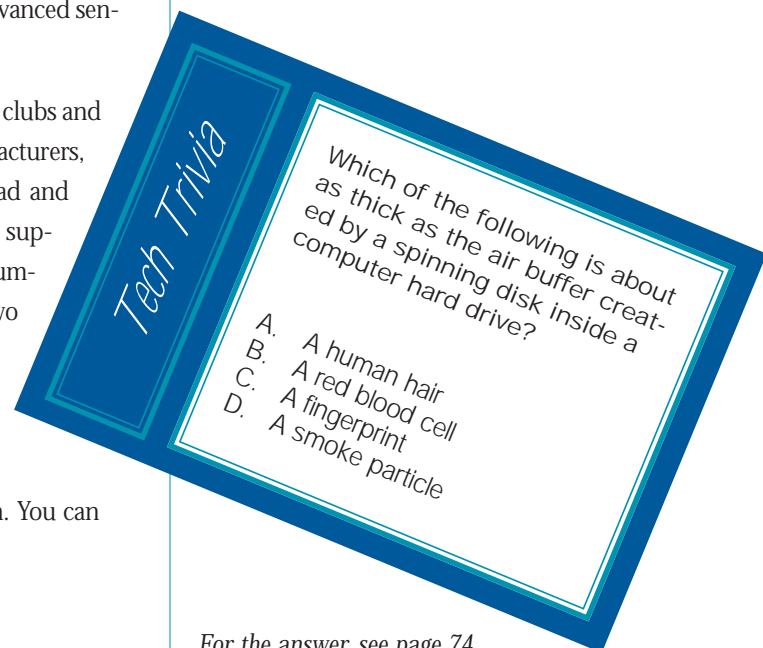
What Does It Mean to You?

Beralcast alloys will be greatly appreciated by both computer users and sports enthusiasts, allowing manufacturers to produce faster, larger hard disk drives and lighter, stronger golf clubs.



What Does It Mean to Our Nation?

Beralcast alloys will lower costs in weight-critical programs such as low-Earth-orbiting satellites for global communications networks, enabling commercial and government space programs to reduce mission budgets.



For the answer, see page 74.

OIL ADDITIVE KEEPS ENGINES HEALTHY

This lubricant repairs worn-out spots caused by metal-to-metal contact in automotive engines, restoring lost power, performance, and gas mileage.



■ RITE SURGE™ (pictured above) is a lead-free engine oil additive developed by Materials Modification.

Before you turn that ignition key, answer this question: Do you know where your car's engine oil is? If you believe the oil is in the engine, you are wrong. Actually, gravity has pulled the engine oil back into the oil pan underneath the car. The oil pump has not yet circulated oil through the engine.

Dry cold starts, as they are called, are particularly hard on your car's engine. Engineering studies show that 70 to 80 percent of all engine wear occurs during that 60 second dry-start period when an engine is first started. Wear is caused by metal-to-metal grinding, and it can destroy vital engine components such as camshafts, leading to engine breakdowns.

Materials Modification, Inc. (MMI; Fairfax, VA), has developed an innovative lubricant that can seal worn-out spots in the engine. By filling these spots, this oil additive can significantly reduce metal-to-metal contact, especially during dry cold starts. Reduced wear also leads to better performance—engine compression and horsepower are increased, giving your car more pep and power. And less engine wear saves you money, in terms of better gas mileage and lower engine repair bills.

Getting the right mix. MMI's oil additive is a unique blend of soft metal and copper powders. Ordinarily, these powders would be difficult to mix because the soft metal nanoparticles do not bond well to copper nanoparticles. But MMI adds several proprietary chemicals to increase particle consolidation and create a homogeneously distributed product. BMD's SBIR program funded MMI to develop this materials technology for self-lubricating bearings in space applications. These bearings would be superior to greased bearings, which are prone to outgassing in the vacuum of space. Bearings are typically found in moving mechanical assemblies.

Before pursuing the automotive engine application, MMI discovered commercial satellite and brazing opportunities. "We believe our materials technology would be great for making self-lubricating bearings for communications satellites," says Dr. T.S. Sudarshan, MMI's technical director. "Most people believe that battery life limits satellite lifetimes, but it really is the bearings. Over time, bearings lose their lubrication and the metal-to-metal grinding often corrupts satellite transmissions." Dr. Sudarshan adds that the technology could also be

used to make high-temperature brazing alloys with the fluidity of soft metal but the strength of copper.

MMI researchers also tested the material, along with regular motor oil, in car engines. These tests were very successful, which encouraged MMI to consider how to introduce this product to the automotive market. Unable to commercialize the technology themselves, MMI sold its rights to a group of individuals with significant experience in the automotive industry. This group formed a company to market the new materials technology as an engine oil additive. For three years after this deal was completed, MMI received royalty payments.

Slick business. The automotive company annually sells more than 4 million cans of the engine oil additive, split evenly between Europe and the United States. In the United States, the company's product can be found on the shelves of many automotive product retailers, including TrakAuto, WalMart, and Kmart.

In recent years, the Environmental Protection Agency has become increasingly concerned about lead-based products and their adverse effects on the environment. It has proposed environmental regulations that would ban the production and sale of many of these products by the year 2000. These regulations could significantly curtail the sale of lead-containing additives for car engines.

To address these environmental concerns, MMI has formulated a new lead-free engine oil additive called RITE SURGE™ while working on a U.S. Army contract. This additive, which is environmentally safe, is specifically designed for high-mileage vehicles. Like its predecessor, it repairs and seals grooves and other damage to engine parts caused by wear. MMI is ready to begin production of RITE SURGE and is currently seeking national distributors.

■ For more information, contact Dr. T.S. Sudarshan via telephone at (703) 560-1371 or via E-mail at sudarshan@compuserve.com. You can also visit MMI's Web site at <http://www.matmod.com>.



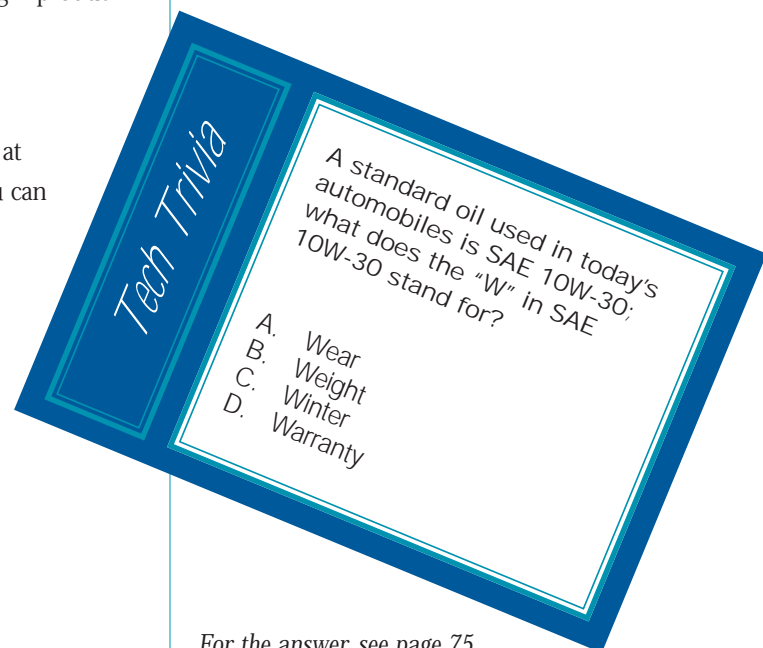
What Does It Mean to You?

Oil additives for automotive engines save you money by preventing untimely engine breakdowns and even vehicle replacements.



What Does It Mean to Our Nation?

Oil additives help car engines achieve better gas mileage, which results in less air pollution.



For the answer, see page 75.